

## REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

**PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE (DD-MM-YYYY) 18-03-2009		2. REPORT TYPE Final		3. DATES COVERED (From - To) From 15-12-2006 to 15-12-2007	
4. TITLE AND SUBTITLE Adaptive Multi-Modal Data Mining and Fusion For Autonomous Intelligence Discovery				5a. CONTRACT NUMBER W911NF-07-1-0059	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Edward J. Wegman				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) George Mason University 4400 University Drive Fairfax, VA 22030-4444				8. PERFORMING ORGANIZATION REPORT NUMBER TR ARL 02	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) US ARMY RDCOM ACQ CTR - W911NF 4300 S. Miami Blvd Durham, NC 27703				10. SPONSOR/MONITOR'S ACRONYM(S) ARO/ARL	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.					
13. SUPPLEMENTARY NOTES The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.					
14. ABSTRACT This proposal addressed the autonomous discovery of relevant information in massive, complex, dynamic text and imagery streams. We began development of a prototype system to mine, filter and fuse multi-modal data streams and dynamically interact with the analysts to improve their efficiency through feedbacks and autonomous adaptation of the algorithms. The plan was to implement four core capabilities: 1) Text and image mining for feature extraction, 2) Multi-modal data fusion, 3) Agent-based adaptive information filtering, 4) Cognitively friendly information visualization. The focus in the first phase of the work was multilingual text search systems as well as geospatial mapping of documents and images.					
15. SUBJECT TERMS automated data mining, streaming data, geospatial Internet localization, Arabic language text mining					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 15	19a. NAME OF RESPONSIBLE PERSON Edward J. Wegman
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U			19b. TELEPHONE NUMBER (Include area code) 703-993-1691

20090325053

## Table of Contents

<b>List of Illustrations.....</b>	<b>ii</b>
<b>Statement of Problem Studied.....</b>	<b>1</b>
<b>Mixed Language Text Database Search.....</b>	<b>2</b>
<b>Streaming Text Data Classification.....</b>	<b>5</b>
<b>Transient Geographic Mapping System.....</b>	<b>7</b>
<b>Bibliography.....</b>	<b>10</b>

## **List of Illustrations**

Figure 1: Overall architecture of the planned system tool.....	1
Figure 2: Block diagram of the Arabic-English text mining system.....	3
Figure 3: Enhanced block diagram for the Arabic-English system.....	4
Figure 4: Document search screen shot.....	4
Figure 5: Example of node tracking by graph based algorithm.....	6
Figure 6: Mercator projection of map application with Russia highlighted.....	7
Figure 7: Plate Carrée projection of map application with USA highlighted.....	8
Figure 8: Winkel Tripel projection of map application with Antarctica highlighted.....	8
Figure 9: Mercator projection with IP point sources lit by intensity of traffic.....	9

## 1 Statement of Problem Studied

Consider the plight of the military situational analyst, who is faced with multimedia sources that stream in data constantly. Data can be structured text, unstructured text, voice, images, and video. The data likely are not English language, the data are likely to be massive in scale, and the data are streaming. The premise of the project was that the analyst needs a system tool to integrate, filter, and present to the analyst for his or her consideration the data that are most likely to be useful. The tool should be a query system that must operate transparently and without significant human fine tuning. The plan was to implement four core capabilities: 1) text and image mining for feature extraction, 2) multi-modal data fusion, 3) agent-based adaptive information filtering, and 4) cognitively friendly information visualization. Together, these will enhance the capabilities of the analysts to discover, assess, and act on embedded intelligence in near real-time. Figure 1 shows an overview of the planned architecture.

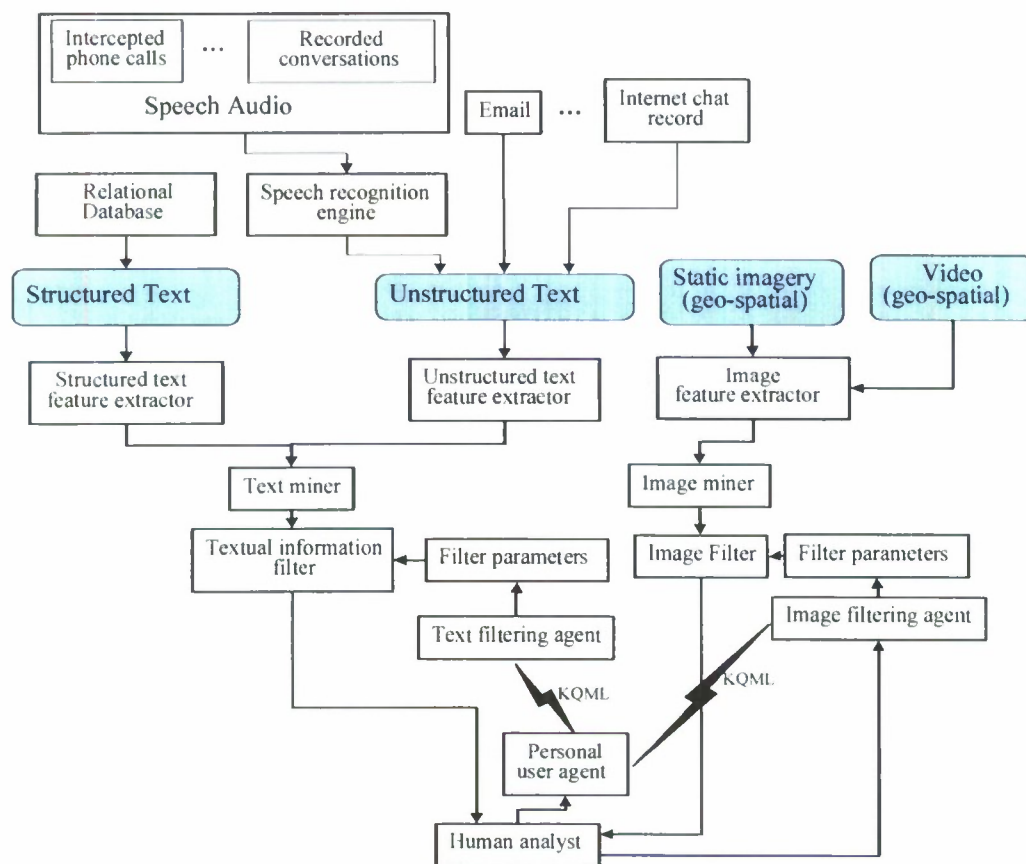


Figure 1: Overall architecture of the planned system tool.

The strategy for development of this rather ambitious tool was to divide the components of the architecture into modules that could be addressed by teams that were to work under the guidance of the investigators capitalizing on the particular skills of the graduate students involved. We had prior experience with speech recognition tools as well as with



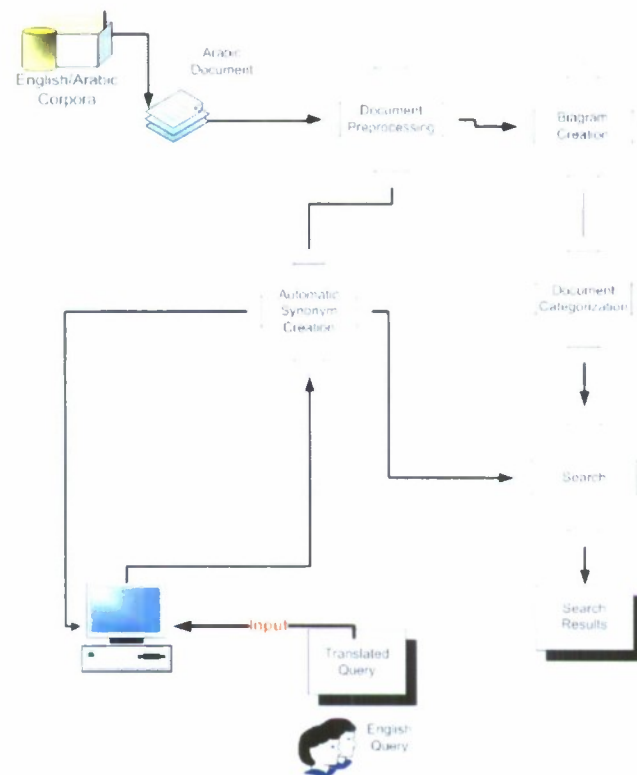
relational data bases. The planned decomposition was to focus on the unstructured text feature extraction, on the geospatial imagery, video, and internet IP locators, and on streaming text data mining.

### **1.1 Mixed Language Text Database Search**

A particularly useful component that was under development was on a mixed language text database search of open literature and intelligence documents. Because of the impetus from the fighting in Iraq, we initially developed a prototype for an Arabic and English mixed database. This project was directed at building a bilingual Arabic/English Web-Based Text Processing system that provides analysts with search results in Arabic based on English language queries. A massive amount of multilingual open source text data is available. Arabic is the official language of Algeria, Bahrain, Comoros, Chad, Djibouti, Egypt, Eritrea, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, United Arab Emirates, Yemen, Western Sahara, African Union Arab League, and the United Nations. The structure of Arabic is quite different from Western languages not only because of the alphabet, but also because of conceptual difference in construction of words and sentences. Typically, vowels are omitted from written Arabic, which is written from right to left. There are approximately 10,000 independent roots and each root can have multiple meanings.

Particles of construction are the letters used to form a word. The particles of signification are used to form sentences. Particles of signification are used to modify verbs, nouns, or both. In Arabic, a noun is a word that indicates a meaning by itself without being connected with the notion of time. Nouns can be, masculine or feminine, qualified or qualificative, definite or indefinite, and diminutive or relative. Nouns also can be singular, plural, or dual. Singulars have more than one plural form and some plurals are not derived from the singulars. Nouns can be proper nouns. A proper noun is the name of a specific person, place, organization, thing, idea, event, date, time, or other entity. Proper nouns can be masculine or feminine, simple and composite. Proper nouns in Arabic do not start with capital letter as in English, which makes it complicated to try to extract them by machines. A simple proper noun is the proper noun composed of only one word, e.g., Muna (feminine) منى, Muhammad (masculine) محمد. Arabic names like Abdul Rahman عبدالرحمن, Abu Saleem أبوسليم, and Abdu Allah عبدالله are considered composite proper nouns. Composite proper nouns are composed of more than one word.

Because automatic language translation is an extremely difficult task, we were not attempting automatic language translation, rather we are suggesting to the analyst a reduced set of Arabic language documents he or she might consider. Arabic is one of the most common languages in the world, but technology has been slow in development for Arabic. This is mostly due to the complexity of the written structure of the language. Unfortunately due the language differences, this technology is usually limited to the language in which it was developed (usually English) and cannot be easily transferred to in different linguistic environments.



**Figure 2: Block diagram of Arabic-English Text Mining System**

In a preprocessing phase, Arabic language documents are background processed, stemmed, and de-noised, i.e. stop words are removed. We developed a capability for synonym creation based on LSI techniques. The version of the system we developed currently supports 81,500 Arabic/English words. For every document in the corpus, the *bigrams* are constructed. A bigram is a word pair where the order of the words is preserved. For example, if the sentence is “Hell hath no fury like a woman scorned.” The stemmed and denoised sentence is “Hell has no fury like woman scorn.” The bigrams are: *hell has, has no, no fury, fury like, like woman, woman scorn, and scorn .;* The sentence ending full stops (like . ! ? : ;) are treated as a word for purposes of bigram development. Bigrams are used as terms in the system so that searches can be made on terms like *nuclear weapons, biological weapons, and mass destruction*. The demonstration database can be bilingual Arabic and English and it currently supports html, Microsoft Word, and text documents. Figure 3 is the enhanced block diagram. Figure 4 is a screen shot from the system. This system, while not implemented is extensible to a Korean-English system. The work reported here was implemented by Eiman Alshammari, a Ph.D. student who is a native Arabic speaker, under the supervision of Dr. Edward J. Wegman and Dr. Yasmin H. Said, who is also a native Arabic speaker and a U.S. citizen.

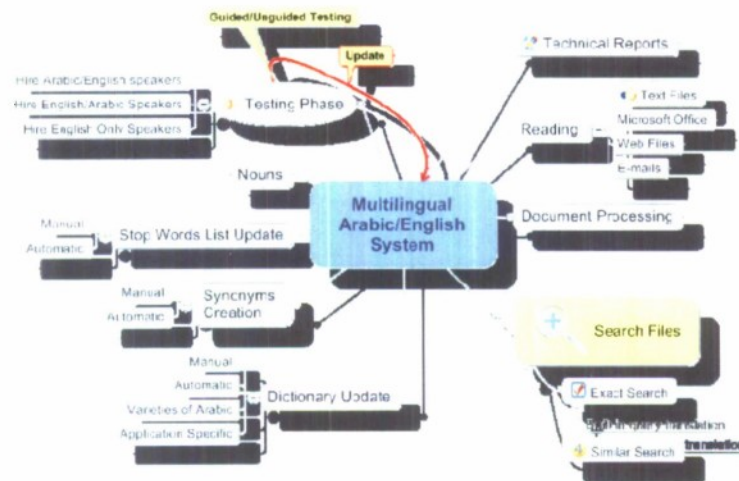


Figure 3: Enhanced block diagram for the Arabic-English System.

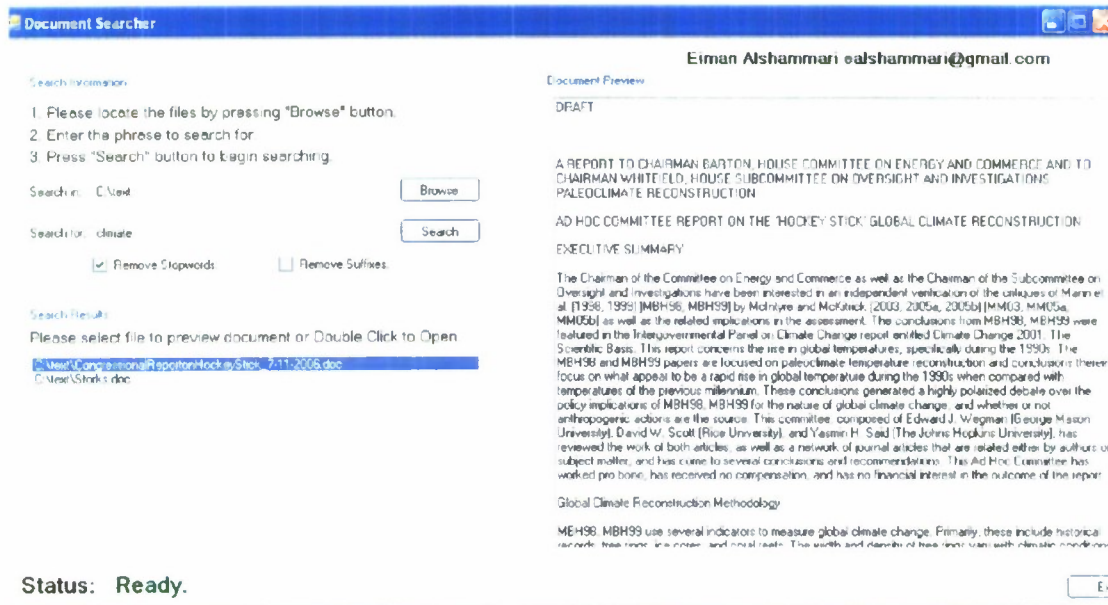


Figure 4: Document search screen shot.



## 1.2 Streaming Text Data Classification

Text processing is usually performed on a fixed corpus of text. The natural question to ask is what to do in the case of streaming news articles, weblogs, military reports, or even research articles when you want to examine them as they evolve in time? Traditionally, in text mining, each document is represented as a vector,  $x_i \in \mathbb{R}^L$ ,  $i = 1, \dots, D$  where  $D$  is the number of documents in the corpus and  $L$  is the number of words in the lexicon. Each dimension of the vector corresponds to a different term in the lexicon. Then,  $x_{ij}$  is the TFIDF weight for word  $j$  in document  $i$ . TFIDF is the so-called term frequency inverse document frequency weight. TFIDF is proportional to the number of times the  $j^{th}$  term in the lexicon appears in document  $i$  and is inversely proportional to  $j^{th}$  term's rate of occurrence in the corpus. Specifically,  $x_{ij} = TF_{ij} \log\left(\frac{D}{b_j}\right)$  where  $TF_{ij}$  is the number of times the  $j^{th}$  term in the lexicon appears in document  $i$ ,  $D$  is the number of documents in the corpus and  $b_j$  is the number of documents that contain the term  $j$ . Terms that occur in every document will have  $\frac{D}{b_j} = 1$  so that  $x_{ij} = 0$ . In contrast, relatively rare words will have a large weight.

Streaming text data presents an alternate problem because the size of the lexicon and the size of the corpus are changing with time. Suppose at time  $t$  a new document is observed. Let  $X_j(t) \in \{0,1\}$  indicate whether term  $j$  occurred in the document read at time  $t$ . Then the approximate document frequency for word  $j$  at time  $t$  is

$$DF_j(t) = \alpha X_j(t) + (1 - \alpha)DF_j(t - 1),$$

an exponential window on the document frequency so that at time  $t$  the

$$TFIDF = TF_{ij} \log\left(\frac{1}{DF_j(t)}\right).$$

We are interested in tracking changes in article topics. To this end we suppose that there are allowing for  $N$  topics to be considered. We formulate a graph model. A graph  $G$  consists of  $V(G)$ , the set of vertices or nodes that represent the  $N$  topics, and the set of edges  $E(G)$  where  $v_i v_j \in E(G)$  is an edge from vertex  $i$  to vertex  $j$ . This is a directed graph. The number of vertices is the order of the graph and the number of edges is the size of the graph. For a graph of order  $N$ , the adjacency matrix  $A$  is an  $N \times N$  matrix with  $a_{ij} = r_{ij}$  if  $v_i v_j \in E(G)$  and  $a_{ij} = 0$  otherwise. Node represent topics, i.e. accumulations of similar articles. Each node has an associated set of words and counts of those words from articles that have been assigned to each node. The edge weights,  $r_{ij} \in [0,1]$ , encode similarities between the nodes. A new article get assigned to the node to which it is most similar based on the cosine similarity. If the new article similarity is less similar to any node than some threshold,  $\tau$ , it initializes a new node or resets an existing node.

In order to maintain the changing lexicon, currently the word counts for each of the  $N$  nodes are kept in a  $N \times L$  matrix,  $X$ , which will be a very sparse matrix. Once the



lexicon reaches its maximum,  $L$ , the oldest  $m$  terms are eliminated. The corresponding columns of  $X$  are eliminated so that the new  $X$  will be an  $N \times (L - m)$  matrix. Then add new terms (columns) onto  $X$ . In order to update graph nodes, Suppose a new document is read. Let  $z_i = (z_{i1}, \dots, z_{iL})$  be the count vector for the terms in the document. Suppose the document is assigned to node  $n$ . Let  $z_n$  be the count vector for the node  $n$  prior to the assignment so that  $z_n = (z_{n1}, \dots, z_{nL})$ . Then the entries of  $z_n$  will be updated by  $z_{nk} = z_{ik}$  if  $z_{nk} = 0$  and  $z_{nk} = \beta z_{ik} + (1 - \beta) z_{nk}$  otherwise. This implements an exponentially smoothed average for the counts in the node.  $\beta$  is adaptive. Let  $s$  be the similarity between the current article and the closest graph node. Let  $\tau$  be a threshold so that any article with the maximum similarity less than  $\tau$  resets the graph node. Let  $\beta$  depend on the maximum similarity by  $\beta = 1 - s$  if  $s \geq \tau$  and  $\beta = 1$  if  $s < \tau$ . This makes large changes in the node when similarity between the document and the node is small, and small changes when the similarity is large.

children&s hypnosi &a	ry cancer i	congo funer know	slogan deros condom	dementin estrogen ovar	room main livo	abstract buist copd	votta cibi homeless	obstetricinn genit tribun
oregon coli beef	waist girl pe	smallpox acambi acam	indoneslan caught sumatra	wme satch see	drug lontree hiz	cucina bella cooki	microchip chip abc	austin dinner minnesota
hispan smoke survel	carton spinach salmonella	ywe seizur bono	trial bugg housten	discourag talk walk	harper commiss cdmonton	kirbi commiss manta	galleri foxrot fax	trier disinfect noroviru
hackbak philosophi heartless	medicaid edwill insur	amgen arancsp medicar	medicar checkbook krughoff	flaxse pruthi flash	kinshasa myster un	trial wille lon	popcorn lung microwav	ili bi d heyman
chcdhealthnews&st hhex arrow	doctor houston concierg	khera doctor test	blood pressur cut	unknown all congo	diagnosi dabrd bipolar	fling pencil recal	design inner vagina	add vagin cosmet
map genom venter	cervic ovarian cancer	sleeper phone sleep	acut ufh pci	nd jenni popular	indystarcom gannett zyprexa	dementin smoker smoke	toddler defici iron	coat drug stent
strength maria joofer	hancock provinc alberta	ritalin tannock adhd	expand insur children	embryo lyukid egg	count cent mental	men prostat asian	mother smoke nicotin	gens adp cbes
commun doctor complaint	overview item —	pah flow tracleer	zyprexa schizophrenia ly	bulimia adolesc psychotherapi	va reiner hour	illi japanes alimta	lipitor statin swich	smoke pct secondhand
west nls nicocito	athlet exercis asthma	million cancer grant	horserac go poll	patient placebo epoetin	stat rheumatoid arthritis	bacteri menoc mening	pirbright famer athletic	hveid dall niece

Figure 5: Example of node tracking by the graph-based algorithm. Here there are 81 nodes. The size of the font represent the frequency of the word in a particular node. This is a screen shot from an animation that can be found online at [http://www.galaxy.gmu.edu/stats/colloquia/AbstractsFall2007/HEALTHNEWS\\_FAST.GIF](http://www.galaxy.gmu.edu/stats/colloquia/AbstractsFall2007/HEALTHNEWS_FAST.GIF)

This work was tested on a Google News dataset. It consisted of approximately 350 articles per day, 70 in each of five categories, World, US, Business, Science and

Technology, and Health. This work was carried out by Dr. Elizabeth Leeds Hohman under the supervision of Dr. Edward J. Wegman. It was part of her Ph.D. dissertation.

### 1.3 Transient Geographic Mapping System

The geolocation tool is designed to enable real-time identification of incoming threats and attacks. The geospatial visualization tool is used for both display and query. The intent is to provide a tool to: 1) geolocate the source IP address of data packets on a world map projection with the idea of locate potential hostile attacks, 2) locate image and video sources based on geospatial metadata, and 3) query a database using geospatial coordinates to obtain multimedia documents. The application was written using Windows API application interface, C++, OpenGL for animation, and the WinPcap library for packet handling. The IP address geolocation tool was based on world map data courtesy of Professor David Wong of GMU, IP location data courtesy of GeoBytes, and GMU traffic data developed under a project with Dr. Wegman as PI funded by the AFOSR. Three projections were considered. The Mercator projection is a conformal mapping that preserves angles and is good for zooming and panning, the Plate Carrée is the simplest to implement and the Winkel Tripei. The latter minimizes distortion so is best for whole Earth maps. On the downside, it is hard to invert, which is only possible numerically.

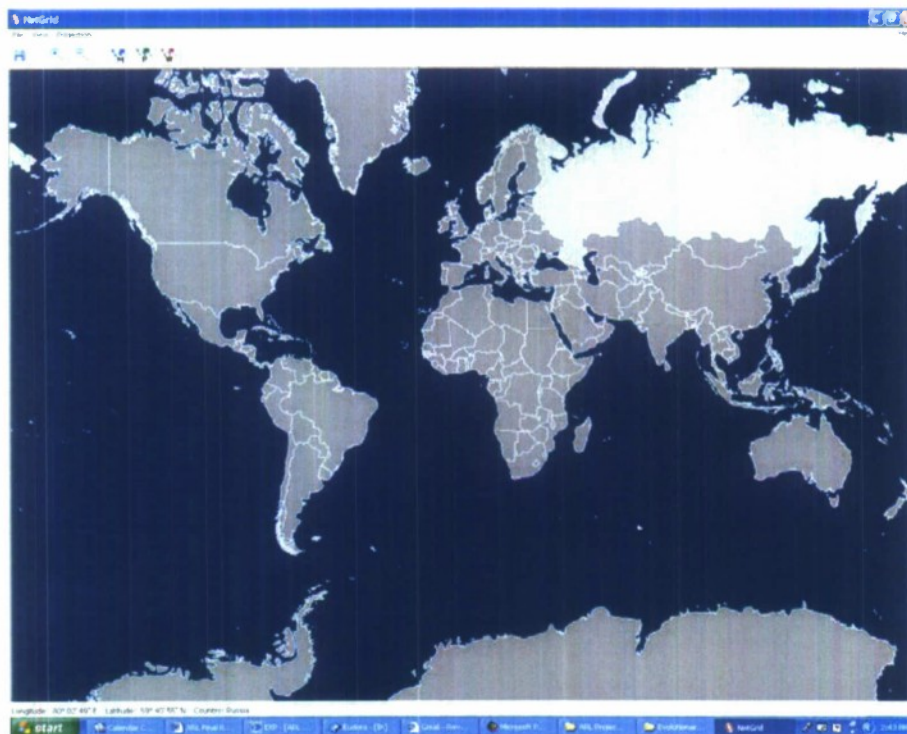
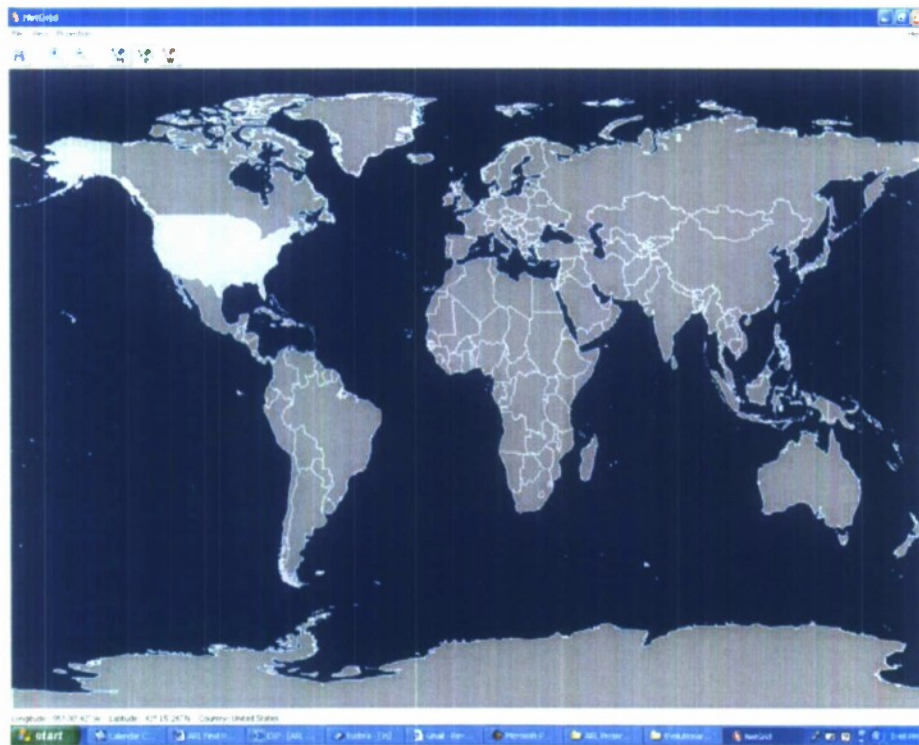


Figure 6: Mercator projection of map application with Russia highlighted.





**Figure 7: Plate Carrée projection of map application with USA highlighted.**



**Figure 8: Winkel Tripel projection of map application with Antarctica highlighted.**

The maps are based on a Delauney triangulation of the surface of the Earth. The drawings are based on the OpenGL software tool. The idea of the transient geographic mapping is to geolocate and event or an object in real time. The point location algorithm locates the Delauney triangle where the given destination point belongs. Once the triangle is known, the country to which the triangle belongs is identified by a table lookup. The algorithm has pre-calculated index points in 1 degree increments. The algorithm starts from the closest pre-located index point and searches triangle by triangle until it locates the triangle to which the given destination point belongs. The complexity for the point location algorithm is  $O(n^{\frac{1}{3}})$  where  $n$  is the number of points. Complexity is improved by using the pre-calculated index points rather than a unique starting point. The GeoBytes database is a database for IP location that provides for each subnet latitude, longitude, city, region, and country. Thus the GeoBytes database provides a the lat-long information and the point location algorithm locates that lat-long information on the map. The WinPcap library provides low-level network access for reading packet headers either real-time or from a stored database. The incoming IP address is read from the packet header and is identified geospatially from the GeoBytes database. The basic idea of transient geographic mapping was to display the source IP geographically in order to dynamically follow where packet headers are coming from, in particular, to rapidly identify whether they were coming from hostile adversaries. The idea is that for each packet, we display a point at the latitude and longitude found in the GeoBytes database. The point has a fading time so that many packets coming from the same source will be represented by a bright point. The default fade time is 1 second, but this can be adjusted. Each point fades out gradually using OpenGL alpha transparency and alpha blending. This work was carried out by In-ja Youn and Felix Mihai under the direction of Dr. Edward Wegman. It is based on an idea suggested by Wegman and Marchette (2003).



**Figure 9: Mercator projection with IP point sources lit by intensity of traffic. Green sources are friendly, red are hostile, yellow is unknown.**



## 2 Summary of Most Important Results

The overall idea of the project was to develop a tool to aid the analyst in identifying information rapidly that may be of interest for command decisions. The overall system diagram is included in Figure 1. The strategy we employed was to modularize the system outlined in Figure 1 and to employ Ph.D. students to develop subsystems whose implementation had enough intellectual challenge to be suitable for Ph.D. dissertations. With continuing funding, these modules would be integrated into the final system. The main achievements of the current project funding were:

- The development of a multi-language search system using terms entered in English, but capable of finding relevant documents in multiple languages. The demonstration languages were English and Arabic, although a Korean-English version could also be rapidly developed based on the prototype. The prototype system was implemented on a windows platform.
- The development of a streaming text classification system capable of automatically identifying evolving topics. The prototype system was also built on a Windows platform with test data deriving from Google News feeds.
- The development of a real-time dynamic geospatial location and query system for locating incoming IP traffic as well as identifying geospatial location of multimedia documents. The latter functionality was not implemented.

Several papers were developed based on research carried out under this project. These papers explicated aspects of the developments here. They are Said et al. (2007, 2008), Said and Wegman (2009), and Wegman and Said (2007). Presentations were given in a number of forums that credited this contract.

## 3 Bibliography

Geobytes IP Locator Files, <http://www.geobytes.com>.

Ipbuker, Cengizhan and Bildirici, I. Oztug (2005) "Computer program for the inverse transformation of the Winkel projection," *Journal of Software Engineering*. 131(4), 125-129.

Mucke, E.P., Saias, I. and Zhu, B.-H. (1996) "Fast randomized point location without preprocessing in two- and three dimensional Delaunay triangulations," In *Proceedings of the 12th Annual ACM Symposium on Computational Geometry*. 274-283.

Shewchuk, J.R. (2002) "Delaunay refinement algorithms for triangular mesh generation," *Computational Geometry: Theory and Applications*. 22(1-3), 21-74.